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# The Effects of Peer-Assisted Learning Strategies and Curriculum-Based Measurement on the Mathematics Performance of Secondary Students with Disabilities

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## ABSTRACT

The purpose of this study was to examine the effects of peer-assisted learning strategies (PALS) and curriculum-based measurement (CBM) on the mathematics performance of secondary students with disabilities. Ten classes with 92 students in Grades 9 through 12 participated. All students were significantly below grade level and received mathematics instruction in self-contained resource rooms. Classrooms were randomly assigned to PALS/CBM or the classroom mathematics program (control). PALS/CBM was implemented twice weekly and CBM was conducted weekly for 15 weeks. PALS/CBM students improved their computation math skills significantly more than control students, but no significant difference was found on concepts/application math skills. On questionnaires, teachers and students indicated that they (a) liked using PALS, (b) felt PALS was helpful in increasing mathematics skills, (c) thought CBM graphs increased motivation to work hard in math, and (d) would like to participate in PALS/CBM again. Results are discussed with respect to research and practice.

have reported that two out of every three students with disabilities experience mathematics problems (McLeod & Armstrong, 1982). Carpenter (1985) found that special education classrooms devote as much as one third of available instructional time to the remediation of mathematics deficiencies. However, even with a substantial portion of their academic time devoted to mathematics (Carpenter, 1985), students with disabilities experience persistent problems related to learning and applying mathematics (Maccini & Hughes, 1997). They usually

- perform basic addition facts only as well as third graders without disabilities (Fleischner, Garnett, & Shepard, 1982),
- show growth patterns in mathematics of only 1 year for every 2 or more years of school (Cawley & Miller, 1989),
- demonstrate proficiency levels equivalent to only fifth or sixth grade (Cawley et al., 1979),
- demonstrate difficulties with word-problem-solving skills (Montague & Applegate, 1993), and

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**M**ATHEMATICS IS A SUBJECT THAT SECONDARY students with learning disabilities will encounter throughout their academic and daily life experiences (Cawley, Fitzmaurice, Shaw, Kahn, & Bates, 1979). Special education teachers

- show limited proficiency on tests of minimum competency (Algozzine, O'Shea, Crews, & Stoddard, 1987; Cawley et al., 1979).

These difficulties usually begin in elementary school and persist through the secondary years (Cawley & Miller, 1989). Problems associated with mathematics can have debilitating effects on secondary students with disabilities and can lead to poor overall school performance and heightened anxiety levels (Mercer & Miller, 1992). It is interesting to note that math deficits shown by students with math disabilities in the research from more than 20 years ago are still being noted by teachers as math weaknesses today (Bryant, Bryant, & Hammill, 2000).

More and more researchers are noting the importance of addressing the needs of secondary students with math disabilities (Patton, Cronin, Bassett, & Koppel, 1997; Wagner, 1990). However, the question remains, What practices are effective for remediating mathematic deficits among secondary students with mathematics disabilities? Traditional mathematics curricula within mainstream and special education classrooms have resulted in poor math performance by secondary students with disabilities (Cawley, Parmar, Foley, Salmon, & Roy, 2001). Given the high incidence of mathematics difficulties for secondary students with disabilities, mathematics interventions that are guided by empirically validated and trustworthy research are warranted (Maccini & Hughes, 1997).

A meta-analysis conducted by Swanson and Hoskyn (1998) concluded that the following are important components for teaching skills to secondary students: (a) using small, interactive group instruction; (b) using directed questioning and responses; (c) breaking tasks down into component parts and fading prompts and cues; and (d) using extended practice with feedback. One empirically based instructional strategy that incorporates these skills and has been shown to be effective for teaching academic skills in classrooms is class-wide peer tutoring (Cook, Scruggs, Mastropieri, & Casto, 1985–1986; Delquardi, Greenwood, Whorton, Carta, & Hall, 1986; Maheady & Harper, 1987; Maheady, Sacca, & Harper, 1988; Osguthorpe & Scruggs, 1986). At the secondary level, however, few studies have examined the utility of dyadic learning for students with disabilities in mathematics (Allsopp, 1997; Kane & Alley, 1980; Maher, 1984; Mellberg, 1980; Roach, Paolucci-Whitcomb, Meyers, & Duncan, 1983; Singh, 1982).

Available research has shown that having secondary students with disabilities act as tutors to low-achieving nondisabled students increases mathematics achievement for both tutors and tutees (Mellberg, 1980; Roach et al., 1983). Similarly, Maher (1984) showed that secondary students with behavior disorders could successfully tutor younger students with mental retardation, increasing mathematic scores for both the tutor and the tutee. Combined, these three studies

demonstrate that acting as a peer tutor can increase the mathematics scores of secondary students with disabilities. Furthermore, Singh (1982) had 11th- and 12th-grade students with learning disabilities tutor 9th- and 10th-grade students with learning disabilities. Results showed that tutees and tutors increased math computation and concepts/applications scores significantly more than did the control group.

Additional research on peer tutoring with secondary students with disabilities found that having a non-learning disabled tutor increased the math scores of students with learning disabilities compared with students taught by a teacher (Kane & Alley, 1980). Furthermore, peer tutoring has been shown to increase prealgebra scores for secondary students with disabilities (Allsopp, 1997). Findings from these studies, in concurrence with Singh (1982), have also suggested that peer tutoring is a viable instructional method for teaching mathematics to secondary students with disabilities.

Peer-Assisted Learning Strategies (PALS) was developed based on class-wide peer tutoring created at Juniper Gardens (Delquardi et al., 1986). It is one form of dyadic instruction that has demonstrated positive effects for teaching computational and concepts/application skills to elementary students with disabilities. PALS was developed as a supplement to the existing math curriculum and can be employed two to three times per week to provide extra individualized practice on skills for which expertise has not yet been achieved. For PALS, students in the same class are paired according to skill level to allow individualized practice on deficit math skills. Three studies (i.e., Fuchs, Fuchs, Hamlett, Phillips, & Bentz, 1994; Fuchs, Fuchs, Hamlett, et al., 1997; Fuchs, Fuchs, Phillips, Hamlett, & Karns, 1995) investigated the effectiveness of PALS with elementary students with disabilities in mathematics. Fuchs, Fuchs, Hamlett, Phillips, and Bentz found that students with disabilities who participated in PALS achieved more in math computation than did students with disabilities in the control group. Fuchs, Fuchs, Phillips, et al. (1999) demonstrated that students with disabilities in the treatment group, which participated in tutoring on computational skills, outperformed students with disabilities in the control group on both acquisition (math computation) and transfer (math concepts/applications) measures. Fuchs, Fuchs, Hamlett, et al. showed that PALS conducted on computation and concepts/applications curricula increased students' skills in these areas. As shown at the elementary level, PALS can increase math skills. These findings at the elementary level, combined with the positive results from Singh (1982) and Allsopp (1997) at the secondary level, suggest the promise of using PALS to increase the mathematics skills of secondary students with disabilities.

In addition to PALS, curriculum-based measurement (CBM) is a well-documented method of tracking and enhancing performance of students with disabilities (Fuchs & Deno, 1990). CBM requires teachers to routinely monitor students' progress toward annual curricular goals (Deno, 1985). Research conducted using CBM documents how teachers can

use these assessments to obtain reliable, valid information on student progress and to design more responsive, effective instruction (Fuchs & Fuchs, 1998). Studies conducted using CBM with mathematics at the elementary level have demonstrated positive increases in student achievement (Fuchs, Fuchs, Hamlett, & Stecker, 1991) and student motivation (Fuchs, Fuchs, Hamlett, & Ferguson, 1992).

A form of CBM was developed in conjunction with math PALS to help teachers determine how to pair students for tutoring and decide which math skill each pair should work on. In a series of studies conducted combining math PALS with CBM in Grades 2 through 6 (Fuchs, Fuchs, Hamlett, et al., 1994; Fuchs, Fuchs, Hamlett, et al., 1997; Fuchs et al., 1995), mathematic achievement was significantly increased for high-, average-, and low-achieving students, as well as for students with disabilities. The pressing need to develop effective instructional strategies at the secondary level for high school students with mathematics disabilities, combined with positive findings at the elementary level for PALS/CBM, indicates the necessity of examining the effectiveness of these methods in secondary special education mathematics classrooms. An extensive literature search suggested that the current study is the first to use math PALS and CBM in high schools with students with disabilities.

Therefore, the purpose of this study was to investigate the effectiveness of PALS/CBM in high school special education mathematics classes. We were primarily interested in effects on mathematics learning. In addition, we examined teachers' and students' perceptions about (a) PALS and CBM in general, (b) the utility of PALS and CBM as a viable methodology for teaching mathematics to high school students, and (c) how hard students worked in tutoring pairs.

## METHOD

### Participants

**Teachers.** Three teachers from three high schools in a southeastern urban school district participated. These teachers taught a total of 10 self-contained mathematics resource classes. One teacher taught five classes, one taught three classes, and one taught two classes. Two were women. One was Caucasian, one was African American, and one was Asian American. Mean age was 43.67 years ( $SD = 13.05$ , range = 30–56); the mean number of years teaching was 11.67 years ( $SD = 7.57$ , range = 3–17). Two teachers were certified in special education and one on a special education waiver with certification in health and physical education. The highest degree earned was a master's plus 42 hours for one teacher and a bachelor's for two teachers.

Without changing the existing caseloads for the teachers, the 10 classes were randomly assigned to two conditions, PALS/CBM and control. One teacher taught two PALS/CBM classes and three control classes, one taught two PALS/CBM

classes, and one taught one PALS/CBM class and two control classes.

**Students.** Students were 92 9th through 12th graders identified as having disabilities. All the students met the state and local eligibility requirements for having a learning disability in mathematics and were enrolled in three public high schools in the district. These students were receiving math instruction in self-contained special education resource rooms and had Individualized Education Program (IEP) mathematics goals. It is important to note that the study began with 120 students, but 28 of these students had dropped out of school by March; therefore, only 92 students began and completed the project.

Using chi-square analyses on categorical data, no reliable differences were found between treatment groups for sex, special education label, and grade level. However, a significant difference was found between treatment groups for race. ANOVAs run on continuous data (grade; number of years in special education; and grade-level performance in math, as judged by teachers) showed no significant differences between treatment groups. See Table 1 for student demographics by condition, along with inferential statistics.

### Measures

**Mathematics Achievement.** The *Math Operations Test-Revised* (MOT-R; Fuchs et al., 1991) assesses first-through sixth-grade math operations skills. The test comprises 50 problems requiring addition, subtraction, multiplication, and division using whole numbers, decimals, and fractions. Students have 10 minutes to answer questions. Responses are scored by number of problems correct. The correlation between the MOT-R and the Math Computation subtest of the *Stanford Achievement Test* (Fuchs et al., 1994) was .78, and internal consistency reliability was .87.

The *Math Concepts and Applications Test* (MCAT; Fuchs et al., 1991) assesses first- through sixth-grade knowledge of number concepts, numeration, applied computation, geometry, measurement, chart and graphs, and word problems. Students have 15 minutes to construct responses to 50 problems spanning Grades 1 through 6. Performance is scored by number of problems correct. Criterion validity with the Concepts of Number subtest of the *Stanford Achievement Test* was .80, and internal consistency reliability was .92 (Fuchs et al., 1994).

In addition, scores from the mathematics portion of the *Tennessee Comprehensive Achievement Test* (TCAP), a high-stakes assessment needed for graduation, were gathered. Students must earn a score of 70 out of a possible 100 to pass. The TCAP consists of math problems involving number concepts, operations and computation, problem solving, algebra, geometry, measurement, and data analysis. High school students can take this statewide assessment twice a year, once in October and again in March. Because this test is optional,

TABLE 1. Demographic Information by Condition

Condition	Gender		Race <sup>a</sup>		Special education label				Grade levels				Grade		Years in special ed		Grade level in math <sup>a</sup>	
	n (%)	n (%)	Black	White	LD	BD	MR	Other	9	10	11	12	M	SD	M	SD	M	SD
PALS + CBM <sup>b</sup>	16 (36)	29 (64)	29 (64)	16 (36)	35 (78)	2 (4)	6 (14)	2 (4)	29 (64)	6 (14)	8 (18)	2 (5)	9.64	.94	5.57	2.84	3.72	.81
Control <sup>b</sup>	16 (34)	31 (66)	18 (38)	29 (62)	33 (70)	2 (4)	6 (13)	6 (13)	28 (60)	9 (19)	8 (17)	2 (4)	9.65	.91	5.11	2.51	3.83	1.18
	$\chi^2 = .05$		$\chi^2 = 8.30^*$		$\chi^2 = 2.77$				$\chi^2 = .444$				$F = .002$		$F = .677$		$F = .275$	

Note. LD = learning disability; BD = behavioral disorder; MR = mental retardation; PALS = peer-assisted learning strategy; CBM = curriculum-based measurement.

<sup>a</sup>As judged by teachers. <sup>b</sup> $n = 5$ .

\* $p < .05$ .

only 56 students in the study took both the October and the March administrations.

One author scored each test using a computer software program (Monitoring Basic Skills) developed by Fuchs et al. (1994). Each answer was entered in the computer, and the software calculated the number of problems correct on the MOT-R and on the MCAT. Interscorer agreement was derived by having a doctoral student reenter 20% of the tests. Percentage of agreement (lower score divided by the higher score) was 97.2 for the MOT-R and 96.4 for the MCAT.

**Questionnaires.** A student questionnaire was administered to explore student beliefs and perceptions of the benefits of PALS and CBM. Each sentence was worded so students could answer on a scale of 1 to 5 (1 = *not true*, 2 = *a little true*, 3 = *kind of true*, 4 = *mostly true*, 5 = *very true*). A scripted introduction was presented, and two sample sentences were reviewed to ensure understanding of the scale. Then each sentence was read aloud, and students circled their answers. Interscorer agreement, determined for 20% of the questionnaires, was 100%.

In addition, a teacher questionnaire was administered to explore teacher perceptions of the benefits of PALS and CBM. Each sentence was worded so teachers could answer on the same 5-point scale. Interscorer agreement, determined for 20% of the questionnaires, was 100%.

## Treatment

**PALS + CBM Treatment.** The PALS + CBM treatment consisted of two separate trainings: one for the PALS programs and one for CBM. Training and implementation for each is discussed in the following sections.

**PALS training.** Teachers taught the routine for PALS to all students in their classes. Training consisted of scripted lessons that incorporated a brief teacher presentation, student practice of the information and principles, and teacher feedback on student implementation (see Fuchs, Fuchs, Phillips, & Karns, 1993, for manual). Training for the computation portion of PALS occurred two times a week for 2 weeks, with each session lasting 50 minutes. The students worked on computation skills using PALS for 4 weeks. At this time, two training sessions were administered on the use of helping and explaining to instruct students in specific strategies that provide conceptual explanations (see Fuchs, Fuchs, Hamlett, et al., 1997, for more detail). To allow students to acquire a comfort level with the PALS procedures, only the computation portion of PALS was administered for the first 8 weeks.

After 8 weeks, training for the concepts/applications portion of PALS was conducted in two sessions within the same week. Again, training consisted of scripted lessons that incorporated a brief teacher presentation, student practice of the information and principles, and teacher feedback on student implementation. Training for the concepts/application portion of PALS occurred two times in 1 week, with each session lasting approximately 40 minutes.

Based on the peer-tutoring procedures of Fuchs et al. (1997), each dyadic activity used the following design features:

1. mediated verbal rehearsal, in which the tutor will model and gradually fade a verbal rehearsal routine delineating procedural steps for completing the activity;
2. step-by-step feedback by the tutor to confirm and praise correct responses and to provide explanations and model strategic behavior for incorrect answers;
3. frequent verbal and written interaction between tutors and tutees; and
4. reciprocity (i.e., both students serve the roles of tutor and tutee in each session).

To conduct PALS, the tutor models a series of verbal statements or questions that the tutee uses to guide him- or herself through concrete knowledge of the mathematical skill. Each series of verbal statements or questions requires a verbal or written action by the tutee. The tutor responds everytime the tutee writes and speaks an answer. When the tutee is correct, the tutor circles the correct answer, and when the tutee is incorrect or expresses confusion, the tutor provides as much additional help as needed.

The problem sheets are divided into four equal parts. For the first problem set, the dyad completes the explanatory interaction just described. The tutee then works the next problem set more independently; the tutee explains his or her work to the tutor and, while the tutor listens, corrects incorrect statements, relying on the same correction procedure used for the first problem set. Then, the two students reverse roles and repeat the same sequence. The tutor offers praise or corrects the tutee as necessary, providing additional help if needed. Every 2 weeks, the tutoring assignments are changed.

PALS occurred 2 days a week and lasted approximately 30 minutes per session. The PALS/CBM treatment lasted for 15 weeks. A research assistant (RA) who was familiar with PALS training and administration was present at all training sessions and at least once per week to observe the PALS sessions, provide support, answer questions, and offer corrective feedback. Because PALS is a supplement to the already existing math curriculum, the students spent the other 3 days a week working as a class from the Houghton Mifflin general math textbook.

**Reinforcement structure.** Motivation is an important component of any high school program for students with disabilities (Mehring & Colson, 1993). For example, Zigmond, Sansone, Miller, Donahoe, and Kohnke (1986) recommended using tangible reinforcers for high school students, such as fast-food coupons and social event tickets. With this in mind, we developed a reinforcement system that provided tangible



rewards, such as money, tickets donated from local sports teams, and certificates from local restaurants.

At the end of each session, pairs totaled up their points. The pair with the highest points wrote their names on the "Highest Scorers of the Day" poster, which was posted at the front of the classroom. At the end of the month, the names on this poster were put in a box and a winner for the month was drawn. The winners then chose an award from a variety of available prizes. This allowed students who attended class often and worked hard during PALS to increase their chances of winning.

**CBM.** CBM is a standardized method for tracking student proficiency in mathematics, reading, spelling, and written expression. Using CBM, teachers identify the curriculum (i.e., mathematics) and level (i.e., Grade 2, 3, 4, 5, or 6) they expect the student to master by the end of the year. The teacher then administers a CBM test at this level once a week, relying on standardized procedure for (a) sampling the curriculum, (b) administering and scoring tests, (c) analyzing the student's performance, and (d) formulating instructional decisions (Fuchs & Fuchs, 1991).

Each CBM probe has the same number of items (computation [ $N = 26$ ]; concept/applications [ $N = 24$ ]) that represent the entire year's curriculum in the same way. Furthermore, every alternate CBM probe samples the same problem types; only the order in which the problems are presented and the numerals contained in the items are changed. Because each CBM probe is equivalent, the teacher can compare a student's performance at different points in time. CBM provides ongoing and dynamic assessment and offers two critical types of information for teachers: (a) standardized, valid procedures for indexing overall performance in basic mathematics skills and (b) diagnostic profiles (Fuchs & Fuchs, 1991). Research shows that with these two types of information, teachers can monitor overall rates of improvement and design sound instructional programs (Fuchs & Fuchs, 1991).

**CBM training.** A scripted training session was used to teach students how to take the weekly CBM computation and applications assessments. Training emphasized test-taking strategies (i.e., start at the top left, do the easy problems first, and do the harder problems last). Students were given training for both the computation and applications probes on the same day. Training lasted approximately 50 minutes. Teachers were given scripted directions for administering the weekly CBM probes. Each week an alternate test form of the appropriate grade-level probe was administered.

Responses on these weekly probes were entered into a software program that scored performance and generated biweekly printouts in the form of a graph and a skills profile for each student. The graph represented the student's progress over time; the skills profile described the student's performance on each skill in the annual curriculum. Every other week, teachers received a copy of each individual student's graph and skills profile. Teachers in turn gave these to the stu-

dents to provide them with information on their progress. Students were taught how to read and interpret their graphs and skills profiles.

The teachers were also provided with a whole-class report that included a class graph and skills profile showing each student's mastery level on each skill of the curriculum. Other items in the teacher report were a list of students scoring below the 25th percentile in their own class; a list of the skills indicating whether the class as a whole had improved, maintained, or declined; a rank ordering of the students on the most recent CBM; and a slope of improvement for each student. In addition, the teacher report provided recommendations for skills to be taught for small-group and whole-class instruction and recommendations for PALS pairs (Fuchs & Fuchs, 1988; see Fuchs, Fuchs, Hamlett, & Stecker, 1991, for technical features of the assessment methods; Fuchs, Fuchs, Hamlett, Thompson, et al., 1994).

**Control Treatment.** Control classrooms were provided instruction using the *Buckle Down on Tennessee Mathematics* (1998) workbook. This program is designed specifically to help students practice mathematics skills that are on the TCAP statewide assessment. Control students worked independently on a workbook arranged into 18 lessons and accompanying worksheets. Lessons consisted of number concepts, operations and computation, problem solving, algebra, geometry, measurement, and data analysis. Each control classroom worked in this workbook five times a week during implementation of the project. No PALS or CBM was used.

### Fidelity

Using direct observation, one author and an RA assessed fidelity. The author and RA were trained to conduct and score the observations, which listed each element of PALS and CBM. Using a checklist, observers judged whether the teacher or student implemented each element correctly; the score was the percentage of correctly conducted elements. Because of considerable stability in implementation accuracy (Fuchs et al., 1994), fidelity was measured at one point in time. Observations were carried out on Week 10 of the 15-week study. Teachers were not informed when observations were conducted. The percentage of correctly implemented elements was 90.3 ( $SD = 10.27$ ) for PALS and 96.2 ( $SD = 3.25$ ) for CBM.

### Data Collection

The MOT-R and the MCAT were administered in whole-class format immediately before and after the 15-week treatment, with the MOT-R given first and the MCAT given second. Total testing time was approximately 25 minutes. Student questionnaires were also administered to the whole class immediately after treatment by the first author and one RA, who had been trained in standard test administration. Imme-

diately after treatment, teacher questionnaires were completed and returned to the RA. Teachers obtained and reported students' October and March TCAP Mathematics scores.

## RESULTS

### Mathematics Achievement

A one-way ANOVA was run on the three pretreatment mathematics achievement test scores to determine comparability of condition (experimental vs. control). No significant difference was found for number of correct problems on any measure (see Table 2). On posttreatment scores, one-way ANOVAs were run with condition (PALS/CBM vs. control). A significant difference was seen between groups, with the PALS/CBM group outperforming the control group on computation scores. Concepts/applications and TCAP skills demonstrated that both groups increased comparably. See Table 2 for descriptive and inferential statistics along with effect sizes.

To assess growth from pre- to posttreatment, one-way ANOVAs were run with treatment (PALS/CBM vs. control). For math computation, the growth of students in the PALS/CBM treatment was greater than that of the control students. A moderate effect size of .40 was found for the PALS/CBM treatment. However, both groups significantly increased in math concepts/applications and TCAP skills. No significant differences were found between the groups for

growth on concepts/applications skills and TCAP scores. See Table 2 for description and inferential statistics.

### Questionnaires

For the questionnaires, scores below 2.4 were considered to show a negative attitude, scores between 2.4 and 2.6 were seen as neutral, and scores above 2.6 demonstrated a positive attitude toward the question.

**Student Questionnaire.** Overall, students' attitudes toward PALS/CBM were positive. Students reported that they liked working with a partner, liked PALS/CBM, and believed it helped them improve and work harder in math. Students showed ambivalence about whether winning prizes and money made them work harder during PALS and whether they would like to do PALS again. See Table 3 for means and standard deviations on the student questionnaire responses.

**Teacher Questionnaire.** Findings from the questionnaire showed that, overall, teachers liked PALS/CBM and thought it (a) was beneficial to the students and to themselves and (b) positively contributed to writing IEPs and individualizing mathematics instruction. Like the students, the teachers were uncertain about the rewards' contribution to improving student performance. In addition, the teachers thought PALS/CBM helped their students prepare for the TCAP, and they reported that they would like to continue to use PALS/CBM the following year. See Table 4 for means and standard deviations on the teacher questionnaire responses.

TABLE 2. Means and Standard Deviations on Computation and Concepts/Applications

Score/time	PALS + CBM		Control		F	ES <sup>a</sup>
	M	SD	M	SD		
MOT-R <sup>b</sup> (computation)						
Pre	24.73	6.74	24.45	7.26	.03	
Post	27.33	6.95	24.37	7.70	3.76*	
Growth	2.60	4.28	-.08	4.84	7.96*	.40
MCAT <sup>b</sup> (application)						
Pre	32.17	7.80	29.58	10.35	1.84	
Post	33.40	8.56	30.87	10.90	4.63*	
Growth	1.22	5.42	1.29	5.81	.00	-.01
TCAP <sup>c</sup>						
Pre	39.70	10.48	35.57	11.09	1.39	
Post	41.10	12.35	40.15	13.71	4.31*	
Growth	1.40	8.24	4.57	13.05	1.21	-.29

Note. PALS = peer-assisted learning strategy; CBM = curriculum-based measurement; MOT-R = *Math Operations Test-Revised* (Fuchs et al., 1991); MCAT = *Math Concepts and Applications Test* (Fuchs et al., 1991); TCAP = *Tennessee Comprehensive Achievement Test*.

<sup>a</sup>Difference between means divided by the pooled standard deviation. <sup>b</sup>df = 1,90. <sup>c</sup>df = 1,54.

\*p < .05.

TABLE 3. Means and Standard Deviations for Student Questionnaire

Question	M	SD
1. I like the CBM graphs and skills profiles.	2.90	1.51
2. Looking at my CBM graph and skills profiles made me want to work harder on my math skills.	3.10	1.56
3. It was helpful to get the CBM graphs and skills profiles.	3.10	1.45
4. I liked PALS.	2.70	1.68
5. I became better at math when I practiced PALS.	3.00	1.68
6. Winning money and prizes made me work harder during PALS.	2.50	1.67
7. I worked hard during PALS so I would become better at math.	3.40	1.48
8. I enjoyed being the highest-earning pair in PALS.	2.90	1.69
9. I liked working with a partner during PALS.	4.30	8.38
10. I don't care about earning prizes or being part of the highest-earning pair during PALS.	2.80	1.54
11. I would like to do PALS again next year.	2.50	1.71

Note. Responses were scored on a 5-point scale, where 1 = *not true* and 5 = *very true*. CBM = curriculum-based measurement; PALS = peer-assisted learning strategy.

TABLE 4. Means and Standard Deviations for Teacher Questionnaire

Question	M	SD
1. I enjoyed participating in the PALS math project this year.	4.33	.57
2. The PALS math materials contributed to improving student math performance.	3.33	.57
3. PALS and CBM increased the math achievement of my high-performing students.	3.33	.57
4. PALS and CBM increased the math achievement of my average-performing students.	3.66	.57
5. PALS and CBM increased the math achievement of my low-performing students.	3.33	.57
6. The possibility of becoming the day's highest-earning pair contributed to improving student math performance.	3.66	.57
7. The possibility of winning an incentive at the end of each month contributed to improving student math performance.	2.66	1.15
8. I liked the CBM graphs and skills profiles that were provided for each student.	5.00	.00
9. I liked the CBM graphs and skills profiles that were provided for the whole class.	5.00	.00
10. Using the CBM graphs and skills profiles helped me become a better teacher.	5.00	.00
11. I used the CBM graphs and skills profiles to individualize instruction for students.	3.33	.57
12. I used the CBM graphs and skills profiles to help plan whole-class instruction.	3.33	.57
13. I used the CBM graphs and skills profiles to write my IEP goals and objectives for individual students.	4.00	1.00
14. I think PALS and CBM helped my students prepare for the TCAP.	3.66	.57
15. I would participate in PALS and CBM next year.	3.66	.57

Note. Responses were scored on a 5-point scale, where 1 = *not true* and 5 = *very true*. PALS = peer-assisted learning strategy; CBM = curriculum-based measurement; TCAP = Tennessee Comprehensive Achievement Test.

## DISCUSSION

The purpose of this study was to examine the effectiveness of PALS/CBM, developed for elementary age students, in promoting mathematics competence among secondary students with math disabilities. Our primary focus was on mathematics learning, but we also examined teachers' and students' insights about whether PALS/CBM is a feasible instructional method for teaching mathematics to high school students and about how hard students worked in tutoring pairs.

Findings suggest that PALS/CBM did promote computational skills for these students with disabilities. The effect size was a moderate .40 standard deviations. This finding, which shows the promise of PALS/CBM to enhance compu-

tational math skills for secondary students with disabilities, is consistent with findings from Singh (1982), Kane and Alley (1980), Maher (1984), Mellberg (1980), and Roach et al. (1983), which all show that peer tutoring is a useful instructional technique to use with secondary students with disabilities. In addition, this study, combined with studies by Fuchs, Fuchs, Hamlett, et al. (1994); Fuchs, Fuchs, Hamlett, et al., (1997); and Fuchs et al. (1995), which were conducted at the elementary level, demonstrates the consistently positive results of using PALS/CBM to teach math computation skills to students with disabilities.

It was therefore disappointing to find that PALS/CBM did not promote the development of concepts/applications skills and TCAP scores for these secondary students. These



results contradict the findings of Singh (1982) and Allsopp (1997), which showed that peer tutoring increased high-order math skills. Furthermore, these findings conflict with the positive increases shown for PALS at the elementary level for students with disabilities on concepts/applications skills. (Fuchs, Fuchs, Hamlett, et al., 1994; Fuchs, Fuchs, Hamlett, et al., 1997; Fuchs et al., 1995).

These findings, however, concur with previous work showing that students with math disabilities exhibit difficulties using effective cognitive and metacognitive problem-solving strategies (Montague & Applegate, 1993), generalization skills (Woodward, 1991), and memory and retrieval processes (Bley & Thorton, 1995) in the service of mathematics. Concept/applications skills, which require generalization skills and cognitive problem-solving skills along with large amounts of reading (i.e., word problems), may require teacher-led direct instruction once students reach the secondary level. This may be the case because of the very severe discrepancies and long-standing difficulties of these students. On the other hand, these findings could also be due to the limited amount of time students used PALS/CBM to teach the concepts/applications portion of PALS. The concepts/applications portion of PALS was implemented for only 7 weeks, whereas the computation portion was conducted for 15 weeks. Given more time to work on concepts/applications skills in the context of PALS/CBM, effects favoring PALS/CBM might have been demonstrated.

In a similar way, because the TCAP consists mainly of higher level mathematics (e.g., multistep problems, prealgebra, algebra, geometry), the minor allocation of time and effort within the implementation of PALS on concepts/applications, relative to computation, may account for the disappointing findings on the TCAP scores. Research has indicated that multistep problems and word problems and the skills associated with them are the most problematic for students with disabilities (Bryant et al., 2000). Implementing additional weeks, as well as using PALS three times per week, instead of two, would have allowed greater emphasis on the concepts/applications component of PALS and might have produced the positive findings documented here on computation at the secondary level and found elsewhere on concepts/applications at the elementary level.

It is interesting to note that the student questionnaire showed that students liked PALS, liked working with a partner, and thought PALS helped them work harder and thus improve their math skills. On the other hand, students were ambivalent about whether winning prizes and money made them work harder during PALS and whether they would like to do PALS again. Inconsistencies found among the students' answers suggested that although some students found being the highest-earning pair to be enjoyable, more than half did not care about earning prizes or being part of the highest-earning pair.

These attitudes suggest that tangible reinforcers may not be as useful for high school students as previously indicated

(Zigmond et al., 1986). These findings instead indicate that an elaborate reinforcement structure with tangible reinforcers may not be necessary to motivate high school students with disabilities to work hard. Responses suggest that the graphs and skills profiles provided via CBM may have served as an adequate basis for motivating students to work hard. This concurs with previous research (Fuchs et al., 1992) demonstrating that CBM increases student motivation. These findings provide a basis for further research examining CBM as a motivational tool at the high school level.

In a similar way, the teacher questionnaire revealed teacher enthusiasm for PALS/CBM. They reported thinking that PALS contributed to improving students' math performance and that PALS/CBM increased the math achievement of students. The teachers unanimously liked the CBM graph and skills profiles provided individually for each student and for the whole class. They reported using the graph and skills profiles to individualize instruction for students, to help plan whole-class instruction, and to write IEP goals and objectives. In addition, the teachers thought PALS/CBM helped their students prepare for the TCAP, and they reported that they would like to continue to use PALS/CBM the following year.

### **Limitations**

In interpreting findings, it is of course important to consider study limitations. The biggest limitation was due to timing and student attrition. At the high school level, time is managed around high-stakes testing. Because we were interested in whether PALS/CBM affected TCAP scores, we were required to plan our study around the fall and spring TCAP testing schedule. Normal implementation time for PALS/CBM is 25 weeks, with concept/application skills conducted for 17 weeks, instead of 7, as in the current study. We hoped to have the study extend through the end of the school year, but the burgeoning dropout rate (28 students total) required us to move up posttesting. As indicated, this limited the amount of time for implementing the concepts/applications skills for PALS/CBM. At the high school level, the push to pass the high-stakes graduation test appears to control, to a great degree, the motivation of students with disabilities to complete the school year. Many, seeing their chances to pass the reading and math basic skills test as improbable, chose to exit school early.

The high-stakes graduation test also seems to influence the nature of instruction. All the control classes used a program published by the TCAP publishers to instruct students. One treatment teacher complained that PALS/CBM took too much time away from the TCAP instructional program. Therefore, further research conducted with PALS/CBM at the high school level should introduce the concepts/applications skills sooner than in the current scheduling for elementary school levels. Further limitations of the study may be the significant difference in the number of minority students in the

experimental group. Because of the low socioeconomic status and related academic problems associated with minority students, this may have affected the outcome of the PALS/CBM group.

### Practical Implications

This study suggests that PALS/CBM is a math program that both high school students with learning disabilities and their teachers like, are willing to use, and believe helps increase mathematics performance. Because basic mathematics skills competence has been shown to escape a significant portion of high school students with learning disabilities (Algozzine et al., 1987), it is important to find a math curriculum that helps improve math skills for these students. The individualization built into the PALS/CBM program allows special education teachers to easily meet the needs of all students in their classes. Furthermore, the supplemental aspect of the PALS program makes it suitable to use with any math curriculum to add an individualized remedial boost. Math PALS uses all the components—small, interactive group instruction; directed questioning and responses; tasks broken down into component parts and fading prompts and cues; and extended practice with feedback—shown in math research to be important to teaching skills to secondary students (Swanson & Hoskyn, 1998). Suggestions for future implementation are to use PALS/CBM for at least 25 weeks and begin the concepts/applications instruction earlier, possibly in the 3rd instead of the 8th week of implementation, to allow more instruction and practice on these skills.

### Conclusions

In sum, the need to identify effective instructional techniques for students with math disabilities at the high school level is critical. Research has shown that students with disabilities leave high school with mathematics proficiency levels that are 6 to 7 years lower than those of their peers (Cawley et al., 1979; Wagner, 1990). Findings from the current study suggest that PALS/CBM may be a viable instructional technique for providing math instruction to high school students with disabilities. The mixed results across computation and concepts/applications, however, reveal the need for further investigation. ■

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### AUTHORS' NOTE

This research was supported in part by Grant H133G90050 from the U.S. Department of Education and by Core Grant H15052 from the National Institute on Child Health and Human Development to Vanderbilt University. Statements do not reflect official policy of either agency.

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Received May 30, 2002

Initial acceptance August 12, 2002

Final acceptance October 21, 2002

